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FLYING PERSONNEL RESEARCH COMMITTEE

OPERATIONAL EXPERIENCE WITH BRITISH EJECTION SEATS

A Survey of Medical Aspects

by

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A I R   M I N I S T R Y

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PART ONE

INTRODUCTION

1. Scope

This is a survey of experience of the emergency use of ejection seats of British design and manufacture. The escapes and attempted escapes included are believed to constitute a complete list of ejections from aircraft flown by the Royal Navy, the Royal Air Force, the Ministry of Aviation (formerly Ministry of Supply), and the British aircraft industry up to 1st July, 1960. It does not include test ejections carried out in the development of ejection seats, or the R.A.F. experience with American seats during the period when the Sabre was used by Fighter Command and 2nd T.A.F. The period covered is of eleven years, from the first ejection, in 1949, to 1st July, 1960.

This survey naturally covers some ejections already dealt with in previous papers, particularly the D.F.S. Abandonment Review, 1960, Latham's review of 1953, and the periodical reports issued by Martin Baker Aircraft Ltd. It is unavoidable that different opinions should exist on the interpretation of some incidents. In this paper a very strict set of criteria has been used to assess the available data, and in every case the original documents have been consulted, rather than interpretations based thereupon. So far as possible, the details of the accident have been obtained from the statements made by the aircrew involved, eye-witnesses and expert witnesses in Boards of Enquiry. The data are often augmented by the completed Ejection Questionnaires returned to I.A.M. and the copies of R.A.F. Form 2855. The medical data on each accident are gleaned from the medical records of the individuals and the special Medical Accident Reports (Form Med.154, formerly Form 2752).

Although reference to the indications for ejection and the mechanism whereby this is executed is frequently necessary, the primary aim of this paper is a medical survey of the difficulties inherent in escape by this means, and the nature, causes and contributory causes of injury during and following ejection.

2. Sources

The information presented here has been gathered from 257 sets of Medical History records (Forms Med.4), 257 files of Boards of Enquiry, 152 medical reports on accidents (R.A.F. Form 2752, R.N. Form 171, or Form Med.154), 104 ejection questionnaires (issued by the R.A.F. Institute of Aviation Medicine), 147 R.A.F. Forms 2855 (reports on escape from aircraft), and at least 85 additional technical reports. Much additional information was gained from correspondence with individuals.

PART TWO

THE GENERAL PICTURE

1. Total Numbers

TABLE I

Aircraft type	Number of aircraft involved	Number of persons ejected	Remarks
Attacker	6	6	
Canberra	9	16	Eight pilots, eight navigators
Gnat	2	2	
Hunter	53	53	Includes a single ejection from two-seat trainer version
Javelin	21	35	Eighteen pilots, seventeen navigators
Jet Provost	1	1	
Lightning	2	2	Includes single ejection from two-seater
Meteor	62	62	
Buccaneer	1	2	
Scimitar	4	4	
Sea Hawk	34	34	
Sea Venom	11	17	Ten pilots, seven observers
Sea Vixen	1	2	
Swift	12	12	
Valiant	2	3	
Vampire	14	25	
Venom	19	19	
Vulcan	3	5	
Wyvern	12	12	
Supermarine 525	1	1	Referred to subsequently as "OTHERS"
Hawker P 1081	1	1	
Boulton Paul P 120	1	1	
Armstrong Whitworth AW 52	1	1	
	273	316	

A total of 316 individuals have ejected from aircraft and have been included in this survey. 273 aircraft were involved. Two-thirds of the ejections were from five types, the Hunter (53), the Meteor (62), the Javelin (35), the Sea Hawk (34), and the Vampire trainer (25). In a few cases ejection has been assumed on the basis of strong circumstantial evidence, such as radio transmission of intention to eject, followed by radio silence.

2. The annual rate

The number of ejections taking place each year is shown in Table II. For some purposes the period has been divided into three three-year groups, 1951-52-53, 1954-55-56 and 1957-58-59. These form convenient groups for comparison, excluding the only ejection before 1951, and the experience for the first half of 1960.

TABLE II

Year	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	Jan-July 1960
Total	1	0	12	16	18	36	35	55	45	35	44	19

Total number of ejections, voluntary and otherwise - 316

TABLE II(a)

1951-1952-1953	1954-1955-1956	1957-1958-1959
46	126	124

It can be seen that the rate is now stable at about 40 ejections per annum.

Table III shows the total broken-down by service, including those aircraft owned and flown by the Ministry of Aviation (M.O.A.) and those aircraft owned by that Ministry but flown by contractors, generally the manufacturers.

TABLE III

Analysis of Ejections by Service

	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	Jan-July 1960
R.N.	0	0	0	1	1	10	8	15	10	12	9	7
R.A.F.	0	0	8	12	16	24	24	35	34	14	30	12
M.O.A. flown	0	0	1	0	0	0	2	1	1	7	0	0
M.O.A. contract	1	0	3*	3	1	2	1	3	0	2	5	0
Private venture	0	0	0	0	0	0	0	1	0	0	0	0
TOTAL	1	0	12	16	18	36	35	55	45	35	44	19

*includes two ejections from a Canberra supplied on loan to a U.S.A. manufacturer.

3. Seats used

Only three seats were not of Martin Baker design and construction, two being Folland seats installed in Gnat aircraft, and one an M.L. seat installed in the Hawker P 1081.

4. Unintentional Ejections

Twenty-one ejections are classified as unintentional or involuntary. The group, comprising three classes, is tabulated in Table IV.

TABLE IV

Circumstances	Total	Fatal	Major Injury	Minor Injury	Remarks
Spontaneous	7	3	4	0	2 Meteor, 2 Javelin, 1 Sea Hawk, 1 Hunter, 1 Scimitar
Mid-air collision	8	6	1	1	2 Meteor, 2 from same Javelin, 1 single from Javelin, 1 Hunter, 1 Sea Venom, 1 Sea Hawk
Ground impact	6	2	4	0	3 Hunter, 1 Sea Venom, 1 Venom, 1 Sea Hawk
	21	11	9	1	

(a) Spontaneous Seven seats were involved in this category. In four cases the seat rode up the rails and was fired because of undetected incorrect installation of the seat, and in a further case the seat rode so far up the rails that the pilot was unable to reach the controls and was forced to eject. Of these five, one was fatal (the seat hit the fin) and the four survivors were seriously injured. In one instance an explosion in the region of the fuselage aft of the cockpit is believed to have caused the operation of the canopy gun and seat in a Scimitar. The pilot died following seat/fin collision and parachute/seat entanglement. The remaining case of inadvertent seat firing during flight occurred in 1953 when the canopy of a Meteor disintegrated in flight and the ensuing turbulence caused the blind to be withdrawn, pulling the seat and firing the seat. The pilot died on ground impact, not having separated from his seat, which was of the non-automatic type.

(b) Mid-air-Collision Eight seats were ejected, with their occupants after collision. Six of these ejections had involved such damage to the seat and/or the occupant as to result in death. Two cases had a more favourable outcome. In one, as a result of a collision, the navigator of a Javelin was ejected, injuring his shoulder during ejection and landed heavily with a damaged parachute. In the other the occupant of a Sea Venom was ejected at 600-900 feet and was uninjured apart from slight spinal injury, not involving fracture.

(c) Ground Impact Six seats are known to have fired during crashes. In several the ejection velocity was probably low as a result of damage to the seat anchorage and/or firing of the primary cartridge only. Surprisingly four of the six persons ejected survived, all with major injury. The fatalities resulted in one instance from an inverted attitude at the time of firing, and from a very high-speed impact in the second.

Table IV(a) shows the annual total of involuntary ejections.

TABLE IV(a)

Involuntary Ejections

1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	Jan-July 1960
0	0	0	0	1	3	2	4	4	2	5	0

5. Under-water Ejection

In one instance the ejection seat has been known to have been operated under-water, with non-fatal serious injury.

6. Voluntary Ejections, in flight

For the major part of this survey, and in all subsequent sections unless otherwise specified the unintentional and under-water escapes have been excluded, leaving a total of 294 ejections for consideration. These are listed by year and type in Table V.

TABLE V

Type	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	First Half 1960	Total
Attacker			1 (0)	1 (0)	1 (0)	2 (1)	0	1 (0)	0	0	0	0	6 (1)
Canberra			2 (1)	0	0	2 (1)	3 (1)	0	3 (0)	3 (0)	3 (1)	0	16 (4)
Gnat								1 (0)	0	1 (1)	0	0	2 (1)
Hunter						2 (0)	7 (3)	20 (4)	10 (5)	2 (0)	5 (1)	2 (0)	48 (13)
Javelin					1 (1)	0	1 (0)	0	2 (2)	11 (5)	9 (2)	6 (0)	30 (10)
Jet Provost												1 (0)	1 (0)
Lightning											1 (0)	1 (0)	2 (0)
Meteor			7 (4)	12 (4)	15 (5)	9 (0)	5 (2)	5 (2)	3 (3)	1 (0)	1 (0)	0	58 (20)
Buccaneer											2 (2)	0	2 (2)
Scimitar											1 (0)	2 (1)	3 (1)
Sea Hawk						6 (3)	4 (3)	11 (4)	3 (1)	5 (1)	2 (1)	0	31 (13)
Sea Venom									2 (1)	4 (0)	4 (1)	5 (0)	15 (2)
Sea Vixen										2 (0)	0	0	2 (0)
Swift						2 (0)	1 (0)	1 (0)	1 (0)	1 (0)	4 (0)	2 (0)	12 (0)
Valiant				2 (1)	0	0	0	1 (0)	0	0	0	0	3 (1)
Vampire							2 (0)	5 (0)	11 (0)	2 (0)	5 (1)	0	25 (1)
Venom						8 (0)	6 (1)	2 (0)	2 (0)	0	0	0	18 (1)
Vulcan								2 (0)	0	1 (1)	2 (0)	0	5 (1)
Wyvern			1 (1)	0	0	1 (0)	3 (0)	2 (0)	4 (0)	0	0	0	11 (1)
Others	1 (0)	0	1 (1)	1 (0)	0	0	1 (1)	0	0	0	0	0	4 (2)

The figures refer to ejections voluntarily executed during flight 294
The numbers in parentheses below the totals refer to fatalities (74)

7. Mortality

Ejections which resulted in fatality are indicated by the figures in parentheses in Table V, which is re-expressed graphically in Figure 1. The overall mortality by the year of ejection is expressed in Table VI, from which is also derived the mortality for the three-year groups 1951-53, 1954-56 and 1957-59.

TABLE VI

Voluntary Ejections, in Flight
(figures in parentheses are deaths)

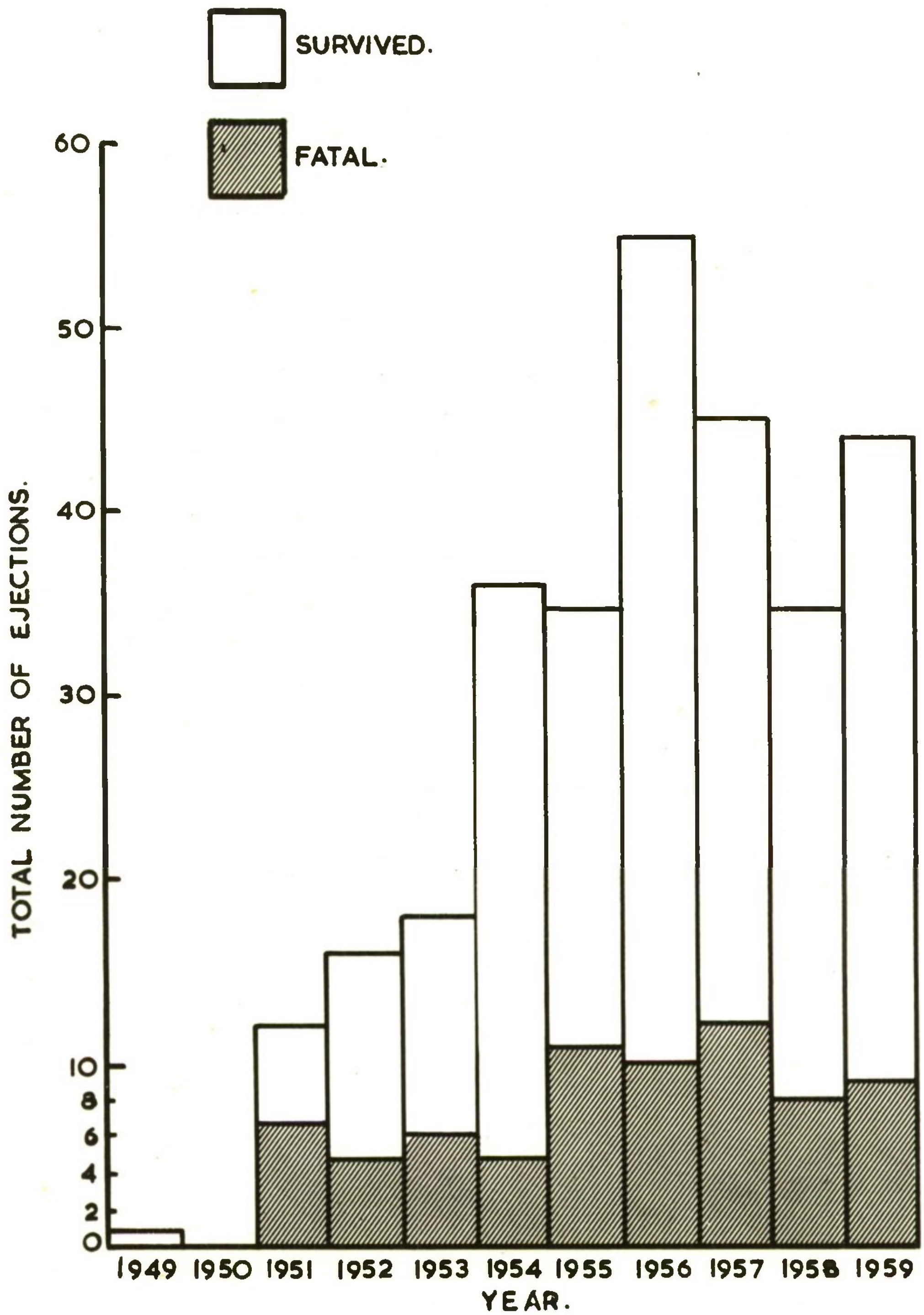
Year	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	Jan-July 1960	Total
Ejections	1	0	12	16	17	32	33	51	41	33	39	19	294
Fatalities	(0)		(7)	(5)	(6)	(5)	(11)	(10)	(12)	(8)	(9)	(1)	(74)
Mortality	0%	-	58%	31%	35%	16%	33%	20%	29%	24%	23%	5%	25.2%
			45 (18) 40%			116(26) 22%			113 (29) 26%				

The mortality for types of aircraft from which more than 12 ejections have been made is expressed in Table VII.

TABLE VII

Mortality for Certain Types of Aircraft

	Canberra	Hunter	Javelin	Meteor	Sea Hawk	Venom	Vampire	Sea Venom
Ejections	16	48	30	58	31	18	25	15
Fatalities	4	13	10	20	13	1	1	2
Mortality	25%	27%	33%	34%	42%	6%	4%	13%



VOLUNTARY EJECTIONS IN THE AIR.

FIG. 1.

PART THREE

FACTORS INFLUENCING THE FATALITY RATE

1. Influence of Altitude on Survival

The altitude (above terrain where this differs significantly from altitude above sea level) at which the ejection was judged to have taken place has been expressed in one of fifteen categories, twelve of which are specifically defined, two are more vague, and a small group of "not known" cases. In order to assess the influence of both altitude and the state of development of seats, Table VIII is arranged to give yearly totals for each altitude band.

TABLE VIII

Mortality related to Altitude and Year
(figures in parentheses are deaths)

Altitude	1949-1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	Jan-July 1960	Total	% mort.
Ground level	0	0	0	0	0	0	0	0	1 (1)	0	0	1 (1)	100%
0-99 ft.	0	1 (1)	0	0	2 (2)	3 (3)	0	1 (1)	3 (3)	3 (3)	1 (0)	14 (13)	93%
100-249	0	0	1 (1)	1 (1)	2 (2)	3 (3)	3 (2)	3 (3)	2 (0)	3 (1)	1 (0)	19 (13)	68%
250-499	0	0	0	0	0	1 (1)	6 (2)	2 (2)	4 (1)	3 (0)	0	16 (6)	38%
500-999	0	1 (1)	0	2 (1)	1 (0)	4 (1)	6 (0)	3 (0)	5 (0)	2 (1)	4 (0)	28 (4)	14%
1,000-1,999	0	3 (2)	1 (1)	2 (2)	5 (0)	1 (0)	7 (1)	6 (0)	6 (2)	2 (0)	0	33 (8)	24%
2,000-4,999	1 (0)	0	3 (0)	3 (0)	2 (0)	3 (0)	8 (1)	7 (1)	3 (0)	10 (2)	6 (1)	46 (5)	11%
5,000-9,999	0	3 (1)	5 (1)	4 (0)	7 (0)	4 (1)	7 (0)	5 (0)	4 (0)	3 (0)	2 (0)	44 (3)	7%
10,000-14,999	0	3 (1)	1 (0)	4 (1)	7 (0)	6 (0)	5 (2)	5 (0)	1 (0)	5 (0)	0	37 (4)	11%
15,000-24,999	0	0	3 (0)	0	2 (0)	3 (1)	4 (0)	2 (0)	1 (0)	4 (1)	1 (0)	20 (2)	10%
25,000-39,999	0	0	0	0	1 (0)	3 (0)	1 (0)	2 (0)	0	3 (0)	2 (0)	12 (0)	0%
40,000-plus	0	0	0	0	0	0	0	0	2 (0)	0	0	2 (0)	0%
"low" or "very low"	0	1 (1)	2 (2)	1 (1)	1 (1)	1 (1)	0	3 (3)	1 (1)	0	0	10 (10)	100%
"medium" or "high"	0	0	0	0	2 (0)	1 (0)	4 (2)	0	0	0	2 (0)	9 (2)	22%
not known	0	0	0	0	0	0	0	2 (2)	0	1 (1)	0	3 (3)	100%
TOTALS	1 (0)	12 (7)	16 (5)	17 (6)	32 (5)	33 (11)	51 (10)	41 (12)	33 (8)	39 (9)	19 (1)	294 (74)	25.2%

In order to derive numbers more suitable for analysis the figures have been combined to give data for the three-year groups and three height bands, below 1,000 ft., 1,000-10,000 ft. and above 10,000 ft. in Table IX. In Table X the proportion of deaths occurring in each wide altitude-band is given.

TABLE IX

Mortality related to broad altitude bands and 3-year periods

Altitude	1951-52-53	1954-55-56	1957-58-59	Total 1949-mid 1960
0-999 plus "low" or "very low"	10 (9) 90%	33 (18) 55%	39 (20) 51%	88 (47) 53%
1,000-9,999 ft.	24 (7) 29%	44 (3) 7%	46 (5) 11%	123 (16) 13%
10,000 ft. plus "medium" and "high"	11 (2) 18%	39 (5) 13%	25 (1) 4%	80 (8) 10%
not known	- - -	- - -	3 (3) 100%	3 (3) 100%

TABLE X

Proportion of Total Deaths occurring at each Altitude Band

Altitude	1951-52-53	1954-55-56	1957-58-59	Total
0-999 ft. plus low and very low	50%	69%	69%	63%
1,000-9,999 ft.	39%	12%	17%	22%
10,000 ft. plus and medium and high	11%	19%	3%	11%
not known	-	-	10%	4%

Further analysis by statistical methods yields the following results. Comparing the actual figures with "expected" figures (the expected figures being based upon the assumption of uniform mortality at all heights), the mortality for ejections below 250 feet is very highly significantly ($P = 0.001$) greater than expected, and above 2,000 feet is significantly ($P = 0.01$) less than expected.

Clearly there is an increase in survival rate for ejection at low altitude in recent years. Although the introduction of the automatic seat has had a profound influence in this respect, perhaps the most important factor has been the development of telescopic guns producing ejection velocities of the order of 80 ft. per second compared with the 50-60 ft. per second of the simple gun. In the majority of ejections the type of gun used has been ascertained and the figures are given in Table XI for the mortality in three height bands with the two types of gun.

TABLE XI

Altitude	60 f.p.s. gun			80 f.p.s gun		
	Survived	Fatal	Total	Survived	Fatal	Total
0-500 ft.	2	22	24	15	10	25
501-2,000 ft.	26	8	34	16	2	18
over 2,000 ft.	114	9	123	41	7	48
TOTAL	142	39	181	72	19	91

Analysis shows the difference in the mortality for ejection below 500 feet for the two gun types (92% and 40%) is highly significant. The relatively minor part played by other improved features of seat development is shown by the fact that in the middle and upper height bands the mortality rates (24% vs 11% and 13% vs 15%) are not greatly different.

2. The Influence of Indicated Air-Speed on Survival

As with altitude, selected "bands" of speed have been chosen for purposes of analysis, each covering 50 kts. In addition, the categories "slow", "medium" and "fast" have been used where accurate estimates of speed are not available. Table XII relates mortality by year to speed at the time of ejection, whilst Table XIII shows the data more conveniently grouped.

TABLE XII

Mortality related to Speed and Year
(Figures in parentheses are deaths)

Indicated Air Speed (knots)	1949–1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	Jan–July 1960	Total
0–49	0	0	0	1 (1)	0	1 (0)	0	0	1 (1)	0	0	3 (2)
50–99	0	0	0	0	0	3 (1)	0	0	4 (2)	1 (1)	0	8 (4)
100–149	0	0	1 (0)	0	2 (1)	6 (3)	11 (3)	8 (2)	6 (2)	4 (1)	2 (0)	40 (12)
150–199	0	2 (1)	5 (2)	4 (0)	9 (0)	7 (2)	13 (1)	8 (3)	6 (0)	8 (0)	6 (1)	68 (10)
200–249	0	1 (0)	2 (1)	2 (0)	4 (0)	4 (2)	10 (0)	7 (0)	3 (0)	4 (0)	7 (0)	44 (3)
250–299	0	0	4 (0)	1 (0)	3 (0)	1 (0)	2 (1)	6 (0)	4 (0)	8 (1)	2 (0)	31 (2)
300–349	1 (0)	0	0	3 (1)	2 (0)	3 (0)	3 (0)	0	1 (0)	0	0	13 (1)
350–399	0	0	0	1 (0)	2 (0)	1 (1)	0	1 (0)	1 (0)	0	0	6 (1)
400–449	0	3 (1)	0	1 (1)	1 (0)	3 (0)	3 (0)	0	2 (0)	3 (1)	0	16 (3)
450 plus	0	0	0	1 (0)	2 (0)	0	0	2 (0)	1 (0)	2 (0)	0	8 (0)
"slow"	0	1 (1)	0	1 (1)	1 (1)	3 (2)	2 (1)	3 (2)	0	4 (2)	0	15 (10)
"medium"	0	1 (1)	0	1 (1)	3 (1)	0	3 (1)	3 (2)	2 (1)	3 (1)	0	16 (8)
"fast"	0	3 (2)	2 (0)	1 (1)	1 (0)	0	3 (2)	0	2 (2)	1 (1)	0	13 (8)
not known	0	1 (1)	2 (2)	0	2 (2)	1 (0)	1 (1)	3 (3)	0	1 (1)	2 (0)	13 (10)
									TOTAL			294 (74)

TABLE XIII

Mortality related to speed and 3-year period
(voluntary ejections)

Speed	1951-52-53	1954-55-56	1957-58-59	Total 1949-mid 1960	Proportion of ejections in this speed range
0-149 plus slow	4 (3) 75%	29 (12) 41%	31 (13) 42%	66 (28) 42%	22%
150-299 + mod.	23 (6) 26%	59 (8) 14%	62 (8) 13%	159 (23) 14%	54%
300 plus + fast	15 (6) 40%	24 (3) 13%	16 (4) 25%	56 (13) 23%	19%
not known	3 (3)	4 (3)	4 (4)	13 (10)	4%

Statistical analysis shows a significantly higher mortality below 150 kts than in other speed ranges. This is considered further below.

3. Combinations of Speed and Altitude

It is of great interest to assess the meaning of the higher mortality at low speed. A most likely factor is the chance that low speed ejections are more likely to take place at low altitude during take-off, approach and landing phases of flight. Table XIV sets out the relevant data.

TABLE XIV

Altitude	SLOW (0-149 kts) (+ "slow")	Mort.	FAST (150 kts or over + "medium") (and "fast")	Mort.	
LOW (0 to 999 ft.) (+ low and very low)	34 (24)	70%	47 (17)	36%	81 (41) 51%
HIGH (1,000 ft. or higher + medium) (and high)	31 (3)	10%	169 (20)	12%	200 (23) 11%
	65 (27)	42%	216 (37)	17%	281 (64) 23%

Statistical analysis of this table shows a very highly significantly raised mortality below 1,000 feet in both speed groups, as was to be expected. There is also a significantly raised mortality for the slow group within the low altitude band, compared with the fast group. In the "over 1,000 ft." series, speed had no significant effect on survival rate.

4. Summary

Insofar as a cause of death can be assigned to the victim of such a complex operation as ejection, the 74 deaths have been tabulated below:

TABLE XV

Ejected too low for the satisfactory function of the equipment	34
"Water casualties"	
probably drowned	4
probably ejected too low over water	4
probable seat malfunction, landing in the sea	2
probably drowned after suffering severe flailing injury	1
possibly fell out of parachute harness into sea	1
Faulty servicing of the seat (including one unconfirmed)	6
Fouled the airframe during or after ejection (including two probables)	5
Seat failure probably due to faulty design or manufacture - Martin Baker	2
Others	2
Release from parachute harness (including two probables)	4
Ejection into unlocked canopy (including one dangerously low also) ..	3
Pre-ejection injury or seat damage	2
Safety harness undone	1
Ejection delayed because of difficulty in releasing canopy and reaching blind	1
Drogue-gun bullet fired through the blind (excluding one case with other features)	1
Probable panic and faulty drill	1
	74

Causes of Death in Fatal Voluntary Ejection

The overall impression is of a strikingly constant mortality rate of around 20-30%, until 1960, when the first half of the year gave an unprecedentedly low fatality rate. The main reason for the steadiness of the mortality would appear to be the way in which the continuous improvement of the performance of seats has been accompanied by an increasing use of the facility at low altitudes where the performance is marginal. Over half the deaths are directly or mainly attributable to lack of sufficient altitude for effective seat operation. The other major categories of causes of death which demand attention are faulty seat servicing and the maintenance of life after ejection over water.

PART FOUR

PREPARATION FOR EJECTION AND SEAT FIRING

1. Canopy and hatch jettison and penetration

Of the 294 voluntary ejections, the circumstances of 278 are well-enough documented to allow accurate assessment of the clearance of the ejection path. In 3 cases the canopy was in all probability jettisoned, in 1 case the canopy was "wound back" before ejection, and in the remaining 12 cases the data are not available. The 236 cases of known canopy or hatch jettison are described in Table XVI, and the 42 cases of canopy or hatch penetration are described in Table XVII.

TABLE XVI

Canopy/Hatch Jettisoned	Non-fatal	Fatal	Total
Clean jettison	162	43	205
Ejected into unlocked canopy	0	5	5
Probably struck by hatch	0	1	1
Hampered by "g" in trying to reach jettison control	6	0	6
Hampered by smoke obscuring controls ..	1	0	1
Difficulty in pulling control handle, or in getting canopy to clear	16	0	16
Injured by fragments of Explosive Bolts	2	0	2
	187	49	236

TABLE XVII

Canopy/Hatch Penetrated	Non-fatal	Fatal	Total
Clean penetration with no injury	14	9*	23
Damaged seat mechanism	-	1	1
Fatal injury (including one ejection into a solid hatch)	-	2	2
Severed parachute harness (perspex fragment)	-	1	1
Concussion	3	-	3
Cuts, abrasions and bruises	12	-	12
	29	13	42

*killed subsequently after successful canopy penetration

Clearly the sixteen cases of difficulty in jettisoning canopies or hatches reported by survivors may indicate that similar difficulty may account for failure to eject in a number of fatal accidents. Fortunately the principal source of trouble, the Meteor Mark 8, has now virtually disappeared from service. Similarly, modification of seats should exclude recurrence of damage to seats during canopy penetration. The roughly 50% incidence of minor injury on canopy penetration is to be noted, although it must be pointed out that the cuts and bruises were generally very minor. Two concussion cases were associated with penetration of Meteor canopies without protective helmets. The third occurred in spite of the use of a "bone dome" when a pilot ejected through the strongly re-inforced canopy of a Wyvern S.4.

2. Turbulence within the cockpit

In 21 of the 220 survived voluntary ejections comment was made about the adverse effects of turbulence following canopy jettison (187 ejections). The type of difficulty, speed and aircraft type are listed in Table XVIII.

TABLE XVIII

TURBULENCE IN THE COCKPIT (Non-fatal voluntary ejections only)

Difficulty reaching the blind owing to turbulence	8
Headgear lost (including one serious case of loss of oxygen mask with subsequent anoxia)	3
Arm or arms sucked out of cockpit without major injury	7
Arm sucked out and fractured or dislocated	2
R/T plug disconnected, disrupting crew intercommunication	1
	21

These 21 cases occurred at the following speeds:

below 200 kts	5
200-300 kts	4
300-400 kts	5
over 400 kts	6
"fast"	1

The following aircraft types were involved:

Meteor	7
Vampire T.11	5
Venom	4
Swift	2
Hunter	2
Gnat	1

Of current aircraft the Vampire trainer is the most serious source of trouble in this respect, and it is well recognised that crew may be severely hampered by turbulence after the canopy leaves the aircraft. This should be borne in mind when cases of failure to eject after canopy jettison are encountered.

3. Seat firing

In the 294 voluntary ejections in this survey the seat was fired by use of the face blind in every case with one possible exception, a fatal accident in which the evidence was equivocal. Various difficulties and variation of technique are described in Table XIX, which refers to 220 survived voluntary ejections.

TABLE XIX

Seat-firing, data on 220 survived voluntary ejections

Hampered in reaching and/or pulling the blind once grasped, owing to turbulence	14
Hampered by positive "g"	6
by negative "g"	4
by alternating "g"	3
by transverse "g"	1
Difficulty reaching over the protective helmet	3
Hampered by a shoulder harness strap slipping over the upper arm	1
Unspecified difficulty reaching the blind	3
Seat fired by pulling the blind with the left hand only	9
" " " " " " " the right hand only	8
" " " " " " " one hand, unspecified ..	2
Two attempts needed before the blind was withdrawn far enough to fire the seat	10
Blind "butted" to fire the seat	2
Blind held with palms facing forwards	1
Blind pulled over one shoulder	1
Blind pulled with one hand until within easy reach of the other	1
Blind pulled with one hand, the other being used to grip the wrist	1

The number of cases in which firing of the seat was delayed by various forms of snag - a total of 21% of the survived ejections - is most disturbing. Many were avoidable, in that better preparation by way of escape procedure practice would have eliminated their occurrence. In particular the twelve cases of failure to fire the seat with the first pull of the blind are of note. Late in 1960 (after the July 1st "deadline" for this survey), a fatality was attributed to mistaken abandonment of an attempt to eject owing to assumption of seat malfunction when, in fact, the only failure was in the incomplete operation of the blind by incorrect technique.

4. Ejection fouling

In Table XX details are given of the 7 cases of known fouling of the airframe or cockpit (excluding involuntary ejections).

TABLE XX

Data from 294 voluntary ejections

	Non-fatal	Fatal	Total
Control column foul, fracturing thigh	0	1	1
Serious lower-limb foul, fracture	3	0	3
Minor lower-limb foul	13	0	13
Canopy or hatch strike, unlocked or failed jettison	0	4	4
Struck fin (one after hitting unlocked canopy)	0	2	2
Minor upper limb foul	1	0	1
Fracture of hand and foot	1	0	1
TOTALS	18	7	25

The lower limb injuries were bruising or laceration from contact with the control column in at least 8 cases (in spite of the provision of stick-snatch in three of the aircraft). At least 5 injuries to hand or foot were caused by contact with the cockpit coaming, and one leg injury was due to a strike against the H.P. fuel cock. The remainder of the cases the cause of injury cannot be specified.

PART FIVE

EJECTION INJURY OF THE SPINE

1. Introduction

There has been considerable debate on the subject of spinal injury during ejection, its diagnosis, treatment and significance. In this survey the following criteria are used.

(a) No post-mortem evidence is accepted, since other traumatic events may have altered the appearances. Therefore, only surviving cases are analysed.

(b) Minor Injury is defined as signs or symptoms in the spine (including coccyx), unassociated with X-ray evidence of bony injury, in which the pain was felt before landing, or the landing was such that the spine was not subjected to excessive loads (i.e. heavy backward landings are excluded). In no case was the result a period of more than seven days off duty, and residual symptoms were not recorded.

(c) Major Injury is defined as a fracture of at least one vertebral body (proved by X-rays) or fracture-dislocation of the coccyx with severe symptoms. One case of prolonged and severe back pain and limitation of movement without radiographic evidence of fracture is included. In any case where a heavy backward or sitting-position landing was made and in which the back pain had not been felt during descent, the lesion is attributed to landing and is not considered as an ejection injury. This applied particularly to cases in which a damaged parachute or seat/parachute entanglement led to a heavy landing. Cases of damage to spinous processes of the vertebrae are not classified as ejection injuries.

2. Incidence

In Table XXI, the cases of minor ejection injury to the spine are listed by year and aircraft type for the 220 survived voluntary ejections in flight which comprise the group under consideration.

TABLE XXI

Numbers refer to 220 survived voluntary ejections. Numbers in parentheses refer to the number of minor spinal injuries on ejection.

Type \ Year	1949-1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	to 1 July 1960	Total
Canberra		1	0	0	1	2 (2)	0	3	3	2	0	12 (2)
Gnat							1	0	0	0	0	1 (0)
Hunter					2	4 (2)	16 (2)	5 (1)	2 (1)	4 (1)	2	35 (7)
Javelin						1	0	0	6 (2)	7 (1)	6 (1)	20 (4)
Jet Provost											1	1 (0)
Lightning										1	1	2 (0)
Meteor		3	8 (1)	10 (1)	9 (1)	3	3 (1)	0	1	1 (1)	0	38 (5)
Swift					2	1	1 (1)	1	1	4	2	12 (1)
Vampire						2	5	11 (1)	2	4 (1)	0	24 (2)
Valiant			1	0	0	0	1	0	0	0	0	2 (0)
Vulcan							2	0	0	2	0	4 (0)
Venom					8	5	2	2	0	0	0	17 (0)
Attacker		1	1	1	1	0	1	0	0	0	0	5 (0)
Buccaneer												0 (0)
Scimitar										1	1	2 (0)
Sea Hawk					3	1	7	2 (1)	4 (1)	1	0	18 (2)
Sea Venom								1	4 (1)	3 (2)	5 (1)	13 (4)
Sea Vixen									2 (1)	0	0	2 (1)
Wyvern					1	3	2 (1)	4	0	0	0	10 (1)
Others	1	0	1	0	0	0	0	0	0	0	0	2 (0)
	1 (0)	5 (0)	11 (1)	11 (1)	27 (1)	22 (4)	41 (5)	29 (3)	25 (6)	30 (6)	18 (2)	220 (29)
Incidence		7%			11%			18%				13%

The overall incidence is 13% with a progressive risk from 7% to 18% during the 3 three-year periods 1951-1959. The incidence should not be over-stressed, as an increase in the severity of injury could be indicated by a rise in major injury rate (see Table XXII) and a fall in minor injury rate.

Table XXII sets out in an identical fashion the major spinal ejection injuries for the same group.

TABLE XXII

Major ejection injury of the spine in 220 voluntary ejections.

Year / Type	1949–1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	to 1 July 1960	Total
Canberra		1	0	0	1	2	0	3	3	2	0	12 (0)
Gnat							1	0	0	0	0	1 (0)
Hunter					2 (1)	4	16 (1)	5 (1)	2 (1)	4 (2)	2 (1)	35 (7)
Javelin						1	0	0	6 (2)	7 (3)	6 (5)	20 (10)
Jet Provost											1	1 (0)
Lightning										1 (1)	1 (1)	2 (2)
Meteor		3	8 (1)	10 (2)	9 (1)	3 (1)	3	0	1	1	0	38 (5)
Swift					2	1	1	1 (1)	1 (1)	4 (2)	2 (2)	12 (6)
Vampire						2	5 (1)	11	2	4	0	24 (1)
Valiant			1	0	0	0	1	0	0	0	0	2 (0)
Vulcan							2 (2*)	0	0	2 (1)	0	4 (3)
Venom					8	5	2	2	0	0	0	17 (0)
Attacker		1	1	1	1	0	1	0	0	0	0	5 (0)
Buccaneer												0 (0)
Scimitar										1	1	2 (0)
Sea Hawk					3	1	7 (1)	2	4	1	0	18 (1)
Sea Venom								1 (1)	4 (1)	3	5	13 (2)
Sea Vixen									2 (1)	0	0	2 (1)
Wyvern					1	3	2	4 (2)	0	0	0	10 (2)
Others	1 (1)	0	1	0	0	0	0	0	0	0	0	2 (1)
	1 (1)	5 (0)	11 (1)	11 (2)	27 (2)	22 (1)	41 (5)	29 (5)	25 (6)	30 (9)	18 (9)	220 (41)
Incidence			11%			9%			24%		50%	19%

*includes one case of back injury without detectable fracture

Here there has been a very striking increase in recent years, with a peak of 30% in the first half of 1960. The overall rate for 1949-mid 1960 is 19%.

The total injury rate (minor plus major) is given in Table XXIII.

TABLE XXIII

Major plus minor spinal injuries in survived voluntary ejections

Type \ Year	1949–1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	to 1 July 1960	Total	%	Major %	Minor %
Canberra		1	0	0	1	2 (2)	0	3	3	2	0	12 (2)	17%	0%	17%
Gnat							1	0	0	0	0	1 (0)			
Hunter					2 (1)	4 (2)	16 (3)	5 (2)	2 (2)	4 (3)	2 (1)	35 (14)	40%	20%	20%
Javelin						1 (0)	0	0	6 (4)	7 (4)	6 (6)	20 (14)	70%	50%	20%
Jet Provost											1	1 (0)			
Lightning										1 (1)	1 (1)	2 (2)			
Meteor		3	8 (2)	10 (3)	9 (2)	3 (1)	3 (1)	0	1	1 (1)	0	38 (10)	26%	13%	13%
Swift					2	1	1 (1)	1 (1)	1 (1)	4 (2)	2 (2)	12 (7)	58%	50%	8%
Vampire						2	5 (1)	11 (1)	2	4 (1)	0	24 (3)	13%	4%	9%
Valiant			1	0	0	0	1	0	0	0	0	2 (0)			
Vulcan							2 (2)	0	0	2 (1)	0	4 (3)			
Venom					8	5	2	2	0	0	0	17 (0)	0%	0%	0%
Attacker		1	1	1	1	0	1	0	0	0	0	5 (0)			
Buccaneer												0 (0)			
Scimitar										1	1	2 (0)			
Sea Hawk					3	1	7 (1)	2 (1)	4 (1)	1	0	18 (3)	17%	6%	11%
Sea Venom								1 (1)	4 (2)	3 (2)	5 (1)	13 (6)	46%	15%	31%
Sea Vixen									2 (2)	0	0	2 (2)			
Wyvern					1	3	2 (1)	4 (2)	0	0	0	10 (3)			
Others	1 (1)	0	1	0	0	0	0	0	0	0	0	2 (1)			
	1 (1)	5 (0)	11 (2)	11 (3)	27 (3)	22 (5)	41 (10)	29 (8)	25 (12)	30 (15)	18 (11)	220 (70)			
Incidence		19%			20%			42%			61%	32%		19%	13%

There are many striking features in this table, apart from the generally high incidence in recent years. Firstly, the incidence in some aircraft types is very high, particularly the Javelin and Swift. Secondly, the Sea Venom has a high rate, but largely of minor injuries. Thirdly, in some aircraft types the rate of spinal injury has risen steeply in the last few years.

3. The site of injury

The level at which spinal injury occurs is indicated by Table XXIV, which lists the number of confirmed and suspected crush fractures at each vertebral level.

TABLE XXIV

Level of Spinal Fracture		40 cases of ejection injury with X-ray evidence of fracture.
CERVICAL		0
THORACIC	1	0
"	2	0
"	3	0
"	4	1
"	5	2
"	6	5 + 1 possible
"	7	4 + 1 "
"	8	6 + 1 "
"	9	7
"	10	10 + 1 "
"	11	9 + 2 "
"	12	18
LUMBAR	1	10
"	2	2
"	3	1
"	4	0
"	5	1
SACRUM		0
COCCYX		4
TOTAL		80 + 6 possible

i.e. average 2 vertebral fractures per man

The table shows a preponderance in the region T.10 to L.1, in which over 50% of fractures occurred. It also indicates that multiple fractures are commonly encountered. The number of vertebral fractures per case is indicated in Table XXV.

TABLE XXV

Number of Fractured Vertebrae per person, classified as major spinal ejection injury.

No fracture seen	1
One vertebra fractured	15
Two vertebrae fractured	16
Three vertebrae fractured	2
Four vertebrae fractured	2
Five vertebrae fractured	1
Six vertebrae fractured	1
One fracture + two probable fractures	1
Two fractured + two probable fractures	1
Three fractured + two probable fractures	1
	41

This shows that, although the "average" man had two fractures, in fact 39% had only one fracture, the mean being high owing to the number of cases of multiple fractures in excess of two.

4. Mechanical factors influencing spinal injury

Several mechanical factors may be involved in the causation of spinal injury on ejection. Each of these should be considered.

(a) The aircraft attitude and behaviour

Negative "g" and or inversion of the aircraft is known to lead to separation between seat and buttocks if the harness is not fully effective, with consequent excessive rate of application of acceleration during seat firing. In Table XXVI such data as are available are arranged in an attempt to assess the importance of this factor in this series.

TABLE XXVI

Aircraft Attitude or Behaviour	Total survived ejections	Minor spinal injury	%	Major spinal injury	%	Major + Minor	%
Steep nose-down	46	6	13%	8	17%	14	30%
Steep bank	8	0	0	3	38%	3	38%
Inverted	11	1	9%	1	9%	2	18%
Negative g	7	1	14%	3	43%	4	57%
Gyrating, uncontrollable	24	2	8%	4	17%	6	25%
Others	124	19	15%	22	18%	41	33%
	220	29	13%	41	19%	70	32%

Although the numbers are small and not statistically valid for comparison, it seems that only when the application of negative "g" is reported does the incidence of spinal injury appear to rise. Only 4 of 70 (5.7%) of all cases of spinal injury are recorded as having occurred under these circumstances.

(b) Loose Harness

It has not proved possible to assess the state of the harness at the time of the ejection, as it is almost invariably reported as "tight". However, it has been suggested that the low incidence of spinal injury in Royal Naval personnel may be attributable to better restraint, since it is so important that the harness should be well-fitted in order to tolerate the acceleration of catapult launch and arrested deck-landings.

(c) Ejection Velocity

Several types of gun and cartridge are in use, and many types of aircraft have had retrospective modification to fit the higher performance type of gun to improve the ejection seat capability. For the purpose of this survey all guns have been classed as 60 ft. per second (this class

includes the 53 ft. per second gun of the Vampire T.11) or 80 ft. per second (all long-stroke telescopic guns). Table XXVII relates spinal injury to gun-type.

TABLE XXVII

Relationship between Spinal Injury and Gun-Type

Spinal Injury	Nil	Minor	Major	Minor + Major	Total
60 f.p.s. gun	114 (81%)	13 (9%)	14 (10%)	27 (19%)	141
80 f.p.s. gun	35 (45%)	15 (19%)	27 (35%)	42 (55%)	77
	149	28	41	69	218*

*in two further cases the gun type could not be ascertained.

Statistical analysis shows a high degree of significance can be attributed to the higher rate of both major and minor spinal injury with the 80 f.p.s. gun than the 60 f.p.s. gun.

(d) Seat Pack

It has been suggested that the type of seat pack and seat-pan may bear some relationship to the degree of spinal injury. The numbers of variations in packs and cushioning materials between pack and user are felt to be too great to allow valid assessment of the role of the pack, although it is not denied that the rigid location of the emergency pack and its consistency may greatly influence the outcome of the vertical acceleration of the seat.

(e) Speed at the Time of Ejection

It is possible that the alignment of the spin during the latter part of the stroke of the telescopic (80 f.p.s.) gun may be adversely affected by wind-blast, pressing the man back and forcing flexion of the spinal column. Table XXVIII sets out the relevant data.

TABLE XXVIII

Spinal injury vs I.A.S. for survived voluntary ejections, using 80 f.p.s. gun

Indicated Airspeed	No injury	Major + Minor Spinal Injury	Total
"slow", "medium", and 0-250 kts	21 (43%)	28 (57%)	49
"fast" and over 250 kts	9 (43%)	12 (57%)	21
	30	40	70

The table indicates that there is no difference between two speed groups.

5. Human factors influencing spinal injury

Several factors pertaining to the individual may influence the susceptibility to spinal injury during ejection.

(a) Weight The acceleration and peak velocity of the seat will be influenced by the ejected mass. This will, in turn, be related to the

mass of the individual. The bodyweight of 215 of the 220 survivors of voluntary ejection was obtained and Table XXIX relates injury to weight.

TABLE XXIX

Weight lbs	Total Survivors	Minor Spinal Injury	Major Spinal Injury	Total Spinal Injury
120-124	1	0	0	0
125-129	5	0	1	1
130-134	14	2	1	3
135-139	11	0	1	1
140-144	22	4	3	7
145-149	11	1	1	2
150-154	32	2	5	7
155-159	18	3	4	7
160-164	24	5	5	10
165-169	16	1	6	7
170-174	14	3	2	5
175-179	15	2	2	4
180-184	11	2	2	4
185-189	5	0	1	1
190-194	4	2	1	3
195-199	2	0	0	0
200-204	4	0	4	4
205-209	3	1	1	2
210-214	1	0	0	0
215-219	1	0	0	0
220-224	0	0	0	0
225-229	1	0	0	0
not known	5	1	1	2
TOTALS	220	29	41	70

Statistical analysis of three groups, under 150 lb, 151-200 lb and over 201 lb reveals that there is no significant difference in the susceptibility to spinal injury. This is contrary to what might have been anticipated.

(b) Height It was not possible to ascertain the sitting height for all individuals, but it was possible to find the standing height of all but 4 of the survivors. It might be anticipated that taller men would have a distinct tendency to flex the spine in order to reach the face-blind operating handle and would therefore have an increased susceptibility to spinal injury. The relevant data are given in Table XXX.

TABLE XXX

Standing height vs ejection spinal injury

Height ins	Total Survivors	Minor Spinal Injury	Major Spinal Injury	Major + Minor Spinal Injury
64	5	0	0	0
65	4	0	0	0
66	6	1	0	1
67	21	4	5	9
68	34	2	8	10
69	26	3	4	7
70	43	9	3	12
71	29	1	7	8
72	20	3	6	9
73	15	4	2	6
74	8	0	3	3
75	3	1	0	1
76	4	1	2	3
not known	4	0	1	1
	220	29	41	770

Again, statistical analysis yields a negative result. There is no significant difference between the injury rate of two groups, of under and over 70 inches height.

(c) Age The age of an individual might possibly be expected to be of significance in the ability of the spine to withstand ejection loads. The

ages of 214 of the 220 survivors of voluntary ejection are given in Table XXXI, together with the incidence of spinal injury.

TABLE XXXI

Age vs ejection spinal injury

Age	Total Survivors	Minor Spinal Injury	Major Spinal Injury	Major + Minor Spinal Injury
19	4	0	0	0
20	10	1	2	3
21	12	1	0	1
22	15	2	0	2
23	22	4	2	6
24	29	3	3	6
25	19	3	3	6
26	18	2	5	7
27	14	0	3	3
28	10	1	4	5
29	8	2	2	4
30	10	1	4	5
31	10	3	2	5
32	9	3	2	5
33	3	0	2	2
34	7	2	1	3
35	5	0	1	1
36	1	0	0	0
37	3	0	2	2
38	0	0	0	0
39	1	0	1	1
40	1	0	0	0
41	0	0	0	0
42	1	0	0	0
43+	2	0	1	1
not known	6	1	1	2
TOTALS	220	29	41	70

Statistical analysis of three groups, aged 19-24, 25-30 and over 31 shows a significantly higher incidence of spinal injury in the 25-30 year-old group, compared with the "expected" rate. The over 31 group, small in numbers, shows a similar trend, but this is not statistically significant.

This result might be due to a discrepancy between age distribution of aircrew operating aircraft with 60 f.p.s. and 80 f.p.s. guns. In fact, there is a significant ($P = 0.02$) difference between the groups, with fewer men of the 19-24 age group using the 80 f.p.s. gun. However, taking the 80 f.p.s. gun series only, there is still a significant variation ($P + 0.01$) between the injury rates at different ages, with a fewer spinal injuries in the 19-24 age group, than in the older groups ($P + 0.02$).

PART SIX

INJURY AFTER SEPARATION FROM THE AIRCRAFT, BUT BEFORE LANDING

1. Spinning and tumbling

Of the 220 survivors, 17 mentioned spinning and/or tumbling as being severe. Of these incidents 4 were associated with damage or malfunctioning seats. Only one man was seriously injured. In this case he separated from an unstable seat at very high altitude and suffered from typical injuries due to spinning.

Among the 74 fatal voluntary ejections there were three cases showing evidence of severe spinning and/or tumbling. Two of these were in seats of non-Martin Baker type, the other was associated with drogue malfunctioning as a result of incorrect servicing.

2. Wind Blast

Nine non-fatal cases showed evidence of wind-blast effects. One had conjunctivitis, four had ocular haemorrhage, two had minor skin lesions attributable to hail, and one had skin petechiae from rain-drops. No unequivocal effects of wind-blast were seen in fatal cases.

3. Flailing

Twenty instances of injury of the limbs due to flailing were noted among the 220 survivors of voluntary ejection. Although strong evidence suggestive of flailing was found in several autopsies on fatal cases, the unequivocal nature of the evidence is felt to preclude inclusion in this series.

Details of the injuries and the speeds at which they occurred are given in Table XXXII.

TABLE XXXII

Flailing Injury

Lower limb minor only	9
Lower and upper minor	2
Upper minor	0
Upper major	1
Upper major and lower major	1
Upper major and lower minor	3
Lower major only	4
TOTAL	20

Minor injury = bruising or stiffness

Major injury = fracture, dislocation and/or severe articular ligament damage.

Speeds

Minor injury only - 1 below 200 kts
3 at 200-300 kts
1 at 300-400 kts
4 at 400 kts plus
1 "moderate"
1 "fast"

Major injury - 2 at 300-400 kts
6 at 400 kts plus
1 "fast"

Severe flailing of the upper limbs following loss of the grasp on the face-blind handle typically caused fracture of the upper third of the humerus or fracture-dislocation of the shoulder joint. Severe lower limb flailing due to lack of leg restraint caused four cases of dislocation of the knee (one bilateral, involving full tears of internal and cruciate ligaments, another complicated by popliteal palsy) and one case of inter-trochanteric fracture of the femur.

An analysis of standing height failed to reveal any relationship between stature and liability to flailing injury.

PART SEVEN

LANDING INJURY

1. General incidence

The occurrence or avoidance of injury upon landing after a parachute descent depends upon a larger number of factors. It is not valid to compare the incidence of injury for aircrew emergency descents with that for parachutist training courses; aircrew parachutes are generally of smaller diameter, the state of preparation, both physical and mental for aircrew is lower and the proportion of descents carried out under unfavourable conditions, such as high wind, darkness, built-up landing areas, and frozen ground is very much greater in emergencies than in formal parachute training.

2. Injury rate

For the purpose of this survey, injuries are classes as

(a) Minor - where the damage was such as to cause absence from duty for a period, but return to a state of fitness for flying within 7 days.

(b) Major - where the injury caused absence from duty for over 7 days (in every case a fracture or concussion).

One case of injury during recovery after landing is also included. Only surviving cases are analysed.

Table XXXIII shows the incidence of landing injury by year and 3-year groups.

TABLE XXXIII

Year	Total Survivors	Minor Landing Injury		Major Landing Injury		Total Landing Injuries	
1949-50	1	0		0		0	
1951	5	0)		2)		2)	
1952	11	0)	11%	3)	30%	3)	41%
1953	11	3)		3)		6)	
1954	27	5)		1)		6)	
1955	22	7)	20%	1)	6%	8)	26%
1956	41	6)		3)		9)	
1957	29	6)		3)		9)	
1958	25	4)	20%	3)	14%	7)	34%
1959	30	7)		6)		13)	
to 1st July 1960	18	3		0		3	
TOTAL	220	41 =	19%	25 =	11%	66 =	30%

LANDING INJURY

3. Injuries

The major injuries occurred in 19 cases after normal descent, in 6 entanglement of parachute and seat caused an increased rate of descent. In view of the varied nature of the injuries, and the interest in the problems of survival and rescue that similar cases might pose, major injuries are listed below.

(a) Fully developed parachute

(i) Relaxed backward landing, fractured T.11, T.12 and L.1 vertebrae.

(ii) Spilled air from parachute to avoid burning wreckage, landed on hard surface, fractured fibula.

(iii) Spinal fracture on ejection, strained knees from flailing, fracture-dislocation of wrist and right ribs 7 and 9 fractured on landing.

(iv) Spinal fracture on ejection, fractured sternum on landing.

(v) Ejection at low altitude fracturing T.12, landed on runway fracturing os calcis of right foot and a left metatarsal.

(vi) Spinal fracture on ejection, heavy landing, dragged, causing concussion.

(vii) Arm sucked out of cockpit and broken, severe contusion of foot on screen arch, fractured tibia on landing.

(viii) Fractured spine on ejection, minor foot injury on screen arch, fracturedtibia and fibula on landing.

(ix) Heavy landing in sitting attitude on survival pack, fractured L.1 and L.2 vertebrae.

(x) Fractured metatarsal landing on rubble.

(xi) Confused or concussed by collision, ejected, dislocation of ankle on landing.

(xii) Heavy sideways landing, fracture-dislocation of shoulder, chip-fracture of ankle.

(xiii) Landed in a tree, fracturing scaphoid bone and receiving multiple severe bruises.

(xiv) Heavy sideways landing, fracture-dislocation of ankle.

(xv) Landed whilst oscillating. Fractured coccyx and sacrum.

(xvi) Heavy landing, fracturing vertebrae L.1 and L.2, and becoming concussed.

(xvii) Heavy backward landing, fracturing vertebra L.1, bruising chest wall.

(xviii) Heavy landing in desert jebel, fracturing talus, spraining neck and becoming concussed.

(xix) Landed in sea, could not release parachute, was towed by helicopter with water-filled parachute, causing extension fracture of the spine.

(b) Partial development or damaged parachute

(i) Snagged parachute on seat with partial development only, fractured T.11 and rib, cauda equina lesion with paralysis of legs.

(ii) Seat-parachute foul, concussion and fractured sacrum.

(iii) Seat and parachute entangled, fractured processes of C.1, C.2 and C.4; crush fractures of T.8, T.9, T.12, L.1 and L.2; fractured pelvis.

(iv) Parachute torn, fractured spine on ejection; flailing fracture of femur, concussed on landing.

(v) Torn parachute, concussed (unconscious ¾ hr.), compound fracture of right leg.

(vi) Landed with parachute deployed between legs, still in seat. Fractured skull.

It is clear that many of these cases would have been quite unable to cope with adverse conditions after landing had help not been readily available. It is also apparent that in a number of cases the bad landing might have been due to the distraction and debility caused by injury during the ejection or descent.

4. Personal factors

(a) Weight In all surveys of injury during parachute training there has been a close correlation between landing injury and weight (Winfield, Bryce) with a steep rise in incidence above about 180 lbs. In Winfield's series the increase was approximately fivefold in groups below

and above 182 lb. The relevant data for the current series are presented in Table XXXIV.

TABLE XXXIV

Weight vs landing injury in survivors of voluntary ejection

Weight lbs	Total Survivors	Minor Landing Injury	Major Landing Injury	Total Landing Injuries
120–124	1	0	0	0
125–129	5	0	0	0
130–134	14	3	1	4
135–139	11	3	1	4
140–144	22	4	5	9
145–149	11	1	1	2
150–154	32	8	3	11
155–159	18	3	6	9
160–164	24	4	3	7
165–169	16	4	0	4
170–174	14	4	0	4
175–179	15	4	1	5
180–184	11	1	3	4
185–189	5	1	0	1
190–194	4	0	1	1
195–199	2	1	0	1
200–204	4	0	0	0
205–209	3	0	0	0
210–214	1	0	0	0
215–219	1	0	0	0
220–224	0	0	0	0
225–229	1	0	0	0
not known	5	0	0	0
	220	41	25	66

For convenience three groups have been derived from Table XXXIV and these have been the subject of statistical analysis.

TABLE XXXV

Landing injury vs weight groups

Weight lbs	No landing injury	Minor landing injury	Major landing injury	Total
100-149	45 (70%)	11 (16%)	8 (13%)	64
150-174	69 (66%)	23 (22%)	12 (12%)	104
175 and over	35 (75%)	7 (15%)	5 (10%)	47
	149 (69%)	41 (19%)	25 (12%)	215

Analysis shows no significant difference between the three groups. This is somewhat surprising, and is probably indicative of a strong predominance of environmental factors in injury causation, overwhelming the effect of weight on liability to injury.

(b) Height Winfield found a relationship between height and injury rate, but dismissed this as a probable result of the association of increased weight of taller men. Table XXXVI shows the relevant data.

TABLE XXXVI

Height vs landing injury in survivors of voluntary ejection

Height (ins)	Total Survivors	Minor Landing Injury	Major Landing Injury	Major + Minor landing injury
64	5	2	0	2
65	4	2	0	2
66	6	2	1	3
67	21	5	3	8
68	34	3	5	8
69	26	3	5	8
70	43	14	3	17
71	29	1	0	1
72	20	5	5	10
73	13	1	2	3
74	8	1	0	1
75	3	2	0	2
76	4	0	1	1
not known	4	0	0	0
	220	41	25	66

If two groups are derived from this series, namely 70 inches and below and over 70 inches, it is found that there is no significant difference in the landing injury rates of the tall and short men.

(c) Age In view of the findings of the analysis of the age factor in ejection injury, it is of interest to study the same factor with regard to landing injury.

TABLE XXXVII

Age vs landing injury in survivors of voluntary ejection

Age (years)	Total Survivors	Minor Landing Injury	Major Landing Injury	Total Landing Injuries
19	4	0	0	0
20	10	1	1	2
21	12	0	1	1
22	15	4	3	7
23	22	1	3	4
24	29	3	2	5
25	19	4	1	5
26	18	8	2	10
27	14	2	3	5
28	10	1	1	2
29	8	2	1	3
30	10	2	0	2
31	10	4	1	5
32	9	1	1	2
33	3	1	0	1
34	7	2	0	2
35	5	3	1	4
36	1	0	0	0
37	3	0	2	2
38	0	0	0	0
39	1	0	0	0
40	1	1	0	1
41	0	0	0	0
42	1	0	1	1
43+	2	0	1	1
not known	6	1	0	1
	220	41	25	66

Analysis is made possible if groups are derived as below.

TABLE XXXVIII

Age	No landing injury	Minor landing injury	Major landing injury	Total landing injuries	Totals
19-25	87 (78%)	13 (12%)	11 (10%)	24 (22%)	111
26-30	38 (63%)	15 (25%)	7 (12%)	22 (37%)	60
over 31	24 (56%)	12 (28%)	7 (16%)	19 (44%)	43
	149 (70%)	40 (19%)	25 (12%)	65 (30%)	214

Analysis shows significantly lower minor and total injury rates for the youngest (19-25) group than for the other ages.

PART EIGHT

DESCENT INTO WATER

1. General

Of the 294 voluntary ejections, 220 of which were survived, 64 took place over water, and 17 of these proved fatal. The mortality rates for land and water descents, 25% and 26% respectively, are remarkably close.

Of the ejections over water, exactly half were from shore or carrier-based Naval aircraft. Sixty landed in the sea, three in lakes and one in a river.

2. Fatalities

The seventeen deaths could be apportioned as follows:-

(a) 9 individuals died as a result of ejection below the minimum safe altitude for the type of seat in use.

(b) 2 fatalities were attributed to failure to separate from the seat. In one instance this was witnessed, but neither seat nor body was recovered from the sea. In the second, the ejection was not witnessed, but the pilot had been instructed to eject and the pilotless aircraft was clearly seen from another aircraft. Subsequent examination of aircraft of the parent unit revealed four with a servicing fault which would prevent separation, and it was assumed that this fault existed in the aircraft involved in the accident.

(c) 3 deaths were attributed to drowning following successful descent in the sea. A fourth was assumed when a pilot announced that he intended to eject at 14,000 feet over the coast, no further transmissions were received, the aircraft was seen to hit the sea, and the body was not recovered. The pilot was known to have been flying without his life saving jacket.

(d) A pilot's body was recovered from a lake several months after the seat had been retrieved. The only sign of trauma was a fractured humerus. He was not wearing a life-jacket and his dinghy had not been released. In view of the circumstances of the accident it is believed that the ejection took place at high speed, the pilot's arm was injured by flailing, and the consequent disability prevented him from releasing his parachute and inflating his dinghy.

3. Location

In only two cases was it recorded that a period of more than two hours was spent awaiting recovery. In one case, a series of misadventure and malfunctioning of equipment led to a period of over 28 hours before the pilot managed to land from his dinghy and seek help ashore. In two cases the SARAH radio beacon was recorded as having been used successfully by R.A.F. personnel. No record was available for the use of the Naval equivalent.

PART NINE

THE TOTAL INJURY PATTERN

It is of interest to survey the data for all the survived voluntary ejections from the point of view of total morbidity. The proportion uninjured comprised 45.5%.

1. Minor injury

Forty four of the 220 survivors (20%) suffered minor injury at some stage of the escape. There is some discrepancy here in that some injuries were recorded as minor, and the sufferers regarded as fit within 7 days whereas in current practice the treatment would be more prolonged. An example is fracture of the coccyx, which should perhaps be regarded as a major injury and which should preclude exposure to risk of further ejection until the displacement has been corrected or the damaged segment allowed to "heal" in its displaced position. For the purpose of this section of the report, however, the criterion of a week or less off duty is used for the classification.

Three cases of recurrent disability have been found.

(a) A pilot suffered bruises and a slightly sprained knee after ejection at high speed in 1957. He was detained in Station Sick Quarters for four days, and then allowed to return to duty, although he abstained from flying for a total of 28 days. A year later he suffered from recurrent pain and moderate disability of the knee joint.

(b) A navigator was bruised and jarred by a heavy landing after ejecting from a Canberra. He is not recorded as having been detained for treatment or removed from duty. Three months later he complained of severe back pain (there were no X-ray appearances suggestive of fracture) for which he was sent to the Medical Rehabilitation Unit for 1 month.

(c) A pilot suffered from bruises of the shoulder and coccygeal region after landing heavily, having ejected from a Meteor. He was troubled thereafter by recurrent pain and he underwent surgical excision of the coccyx one year later.

2. Major Injury

Seventy-six (35%) of the survivors were seriously injured, in terms of time off duty. For a number of reasons, particularly in the case of civilians and ejections in 1960, full data concerning the time of treatment and the duration of restriction of flying duty has not been obtainable for 22 servicemen

and 5 civilians. For the remaining 49 cases, the following break-down will indicate the seriousness of the injuries received.

Number of individuals achieving flying status and full category vs time

	1 wk-1 month	1-3 months	3-6 months	½-1 yr	1-2 yrs	2 yrs +	Total
Return to any flying as aircrew	0	16	10	7	0	0	33
Return to full A1 category	0	7	10	4	0	1	22

There were 4 cases of permanent restriction from all ejection seat use (one man having ejected twice and fractured his spine on both occasions) and one case of recurrent disability with loss of aircrew status after 6 years. Several other cases appear unlikely to achieve a full A1 category.

PART TEN

DISCUSSION

1. Mortality

The numerical size of the sample is of great importance in assessing the true implications of the mortality associated with the use of the ejection seat. For example, a design or servicing fault may lead to one or possibly two fatal incidents before remedial action is effective in preventing recurrence. In a service experiencing several hundred ejections a year the effect on mortality statistics will be very small, whereas in the case of a service with only twenty-five ejections per annum, one such incident will raise the mortality by 4%.

The largest series of ejections available is that of the U.S. Air Force for the period 1950-1959 inclusive, presented by Col. K.E. Pletcher to the Aerospace Medical Convention in 1960. The total over that period amounted to 1,897 ejections, a six-fold increase over the British series which covers Air Force, Navy and civilian ejections. The overall mortality, 19%, was a little lower than that in the British series, with a trend towards reduction over the past 4 years. The fatality rate below 1,000 feet above ground level was 62%, even higher than in our own series. On the other hand, the mortality at low speed was low, whereas our own was high. The fatality rate for descent into water was identical to that on land, a strikingly similar finding to that in the British series.

The U.S. Navy experience up to the end of 1959 was of 669 ejections. Again, the mortality rate was, at 17%, not much lower than our own, with the majority of deaths occurring as a result of ejection below 1,000 ft. Of the 69 ejections below 1,000 ft., 68% resulted in death, and this group comprised 40% of all fatal ejections.

The first 100 ejections from French-operated aircraft were analysed by Fabre in 1959. The mortality was 28%, and the majority were killed as a result of ejection at an altitude below the minimum for satisfactory function of the seat.

2. Ejection Injury

The unclassified literature contains few papers giving the incidence of spinal injury on ejection. The 100 escapes studied by Fabre showed 8 fractured spines among the 72 survivors.

It is undeniable that the spinal fracture rate in the British series is high, by any standard, and this rate has risen concurrently with the improvement in the mechanical features of the seat serving to reduce the minimum altitude for safe ejection. A crush fracture of the spine, in itself a cause of little pain and debility is seemingly a small price to pay for survival from a situation

which would otherwise be lethal. However, the epithet "slight" which has been applied to this type of fracture must be viewed in the light of operational implications. Admittedly many who have suffered spinal compression fracture are only slightly handicapped, and permanent disability or recurrence of symptoms are rare, but a period of 4 to 6 months total exclusion from flight in aircraft with ejection seats is a serious impairment to unit efficiency, and a serious interruption in a highly skilled career. Such a period of restricted activity is essential, however for the risk of a second ejection within the period of re-consolidation of the vertebral bodies is great, and quite unacceptable.

A number of factors have been claimed as "the" cause of spinal injury. Of these, negative 'g', although a potent cause, can be excluded since it has contributed to a very small proportion of the total cases. The type of cushion and survival pack may be important. This factor has not been analysed in this report, because it is felt that the numbers of types is too great, and the associated equipment (such as gun-types, harness) so varied, that groups are too small for valid comparison.

Difficulty in reaching the blind over a protective helmet and visor would seem a very potent cause of spinal flexion and increased risk, but the analysis of data fails to show any relationship between stature and injury. Similarly, weight, influencing ejection velocity is not related to injury susceptibility.

Two clear correlations emerge from this study. The first is the association of the telescopic (80 ft. per second) gun with spinal injury much more frequently than the simple gun. Secondly, the Royal Navy has a very much lower spinal fracture rate than the Royal Air Force. This is difficult to analyse. Certainly the absence of adequate X-ray facilities at sea may lead to a few "missed" cases, but symptoms experienced would tend to show up as a raised "minor" injury rate, and this is not so. The most probable factor is associated with the use of the safety harness. Loosely or incorrectly worn harness can lead to pelvic displacement and spinal flexion during ejection. It is imperative for catapult launching and deck-landing that the torso should be firmly restrained by the harness, and it is undoubtedly true that more attention is paid to harness fit and adjustment by Naval personnel than their Royal Air Force colleagues. It is also true that a minor variation in the routeing of the harness in some Naval aircraft, to enclose the survival pack will account for better pelvic restraint in the relevant aircraft types.

3. Other injuries

It seems unlikely that, with the present types of aircrew parachute, the landing injury rate could be substantially reduced. The risks of training by actual jumps may be high in relationship to the benefits gained. From examination of the records, it is apparent that failure to lower the survival pack has been a possible cause of injury on a number of occasions. Automatic lowering might prove a marked advance in this respect.

Leg flailing was, at one time, a very serious hazard, but the development of leg-restraint has reduced the risk considerably. Further development may be

necessary to ensure protection at very high indicated air-speeds. Arm-restraint has not yet been incorporated in seats, and serious injury with subsequent reduction of survival chances will continue to occur until such restraint is available.

4. Training

Many instances have been discovered where ignorance concerning the mode of operation of the equipment has proved hazardous. This applies equally to servicing personnel. So far as aircrew are concerned, the commonest faults seem to be in the comprehension of the actual sequence of events in ejection with linked canopy jettison (e.g. the second delay is not anticipated, and the correct mode of blind operation is not understood).

PART ELEVEN

RECOMMENDATIONS

From the above survey it is felt that the following recommendations are indicated.

1. The increased chance of survival at low altitude resulting from the use of the telescopic gun should be made available to all aircrew flying aircraft with ejection seats.

2. The importance of attitude and height on ejection seat performance should be stressed repeatedly to aircrew, in an attempt to reduce the number of ejection failures due to insufficient altitude.

3. The seat-firing drill taught on training rigs should be realistic and include emphasis on the correct means of withdrawing the firing gear, the simulation of any delays between canopy jettison and seat firing, and the procedure in the event of firing failure following the first pull on the blind.

4. The importance of sitting position should be stressed and vigorous efforts should be made to improve the positioning of the body at the time of ejection. The negative g restraint strap at present being introduced should help in this matter, but the better answer would appear to be in automatic pre-ejection harness tensing as is incorporated in some American seats.

5. Arm restraint should be developed for seats in high-performance aircraft and leg restraint should be provided on all seats.

6. As a solution to the problems of ejection injury of the spine, and improved very low altitude seat performance, the rocket catapult is worthy of close attention. American experience has been very encouraging, although two snags have been encountered. Firstly, sequencing with concomitant delay is inevitably necessary in two-seat aircraft, since the efflux from the rocket is likely to be so damaging to adjacent personnel. Secondly, the high trajectory actually reduces the chances of survival if ejection is carried out at low altitude in an attitude of part-vertical bank.

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